Rotary-Screw Trap Capture of Chinook Salmon Smolts

with Survival and Production Indices

for the Tuolumne River in 1997

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1997 Tuolumne River Rotary-Screw Trap Monitoring Report

Introduction

Fall-run chinook salmon populations in the San Joaquin River Basin have fluctuated widely and declined throughout the latter portion of the 20th century. Adult spawning escapements reached the lowest recorded levels during the 1987 to 1992 drought (CDFG, 1990 and 1993), with three consecutive years below 150 adults returning. Low spawning escapements have persisted since that time although they have begun to rise in recent years. Recovery may continue to be slowed by the poor production during several previous consecutive brood years and the repetition of lowered total reproductive capacity when recruits from those brood years return as adults.

Variability in spawning escapement is influenced by a number of factors including tributary and main stem San Joaquin River flows during the smolt outmigrant period (CDFG, 1987 and 1992; USFWS, 1987 and 1992). Recent evaluation efforts have focused on the survival of smolts outmigrating from the San Joaquin River. Smolt survival appears to be strongly affected by streamflow (e.g. CDFG, 1995 and 1996).

California Department of Fish and Game (CDFG), Modesto/Turlock Irrigation Districts (M/TID) and United States Fish & Wildlife Service (USFWS) desired a tool to help refine water management in the Tuolumne River to protect the smolt life stage of chinook salmon. Since 1986, studies have attempted to define the relationship between streamflow and smolt survival in the Tuolumne River. Similar efforts were initiated on the Stanislaus and Merced rivers as well as the San Joaquin River Delta.

Test and control groups of coded-wire-tagged (CWT, half size) smolts from the Merced River Hatchery have been released into the Tuolumne River for survival studies in 1986, 1987, 1990, 1994, 1995, 1996 and 1997 (for locations see Figure 1). "Test" groups are released in the upper river, near LaGrange and the "control" groups are released in the lower river, near the mouth.

Recoveries in a Kodiak trawl at Mossdale on the San Joaquin River and at other locations are used to develop "survival rate indices" based on the proportions of smolts recovered from the test and control groups. Information on migration rates and routes are obtained as well. These survival indices are then compared to streamflows (and other physical parameters) occurring in the test reach to help define relationships and monitor responses to provide useful information for fishery and water management decisions.

Rotary-screw traps (RSTs) have been used to sample outmigrant salmon smolts at various locations in the Pacific Northwest (e.g. Roper and Scarnecchia, 1996 and Thedinga et. al. 1994). The parties interested in Tuolumne River smolt survival evaluations decided to test this method in conjunction with the Kodiak trawl at Mossdale and recoveries elsewhere for; a) indexing smolt survival and b) possibly indexing total numbers of smolts leaving the Tuolumne River (smolt production).

Limited duration sampling with RSTs was performed in 1995, 1996 and 1997 in conjunction with the ongoing smolt survival index studies (CDFG, 1995 and 1996) to evaluate their utility for survival and production indices (or estimates) in the Tuolumne River. This report

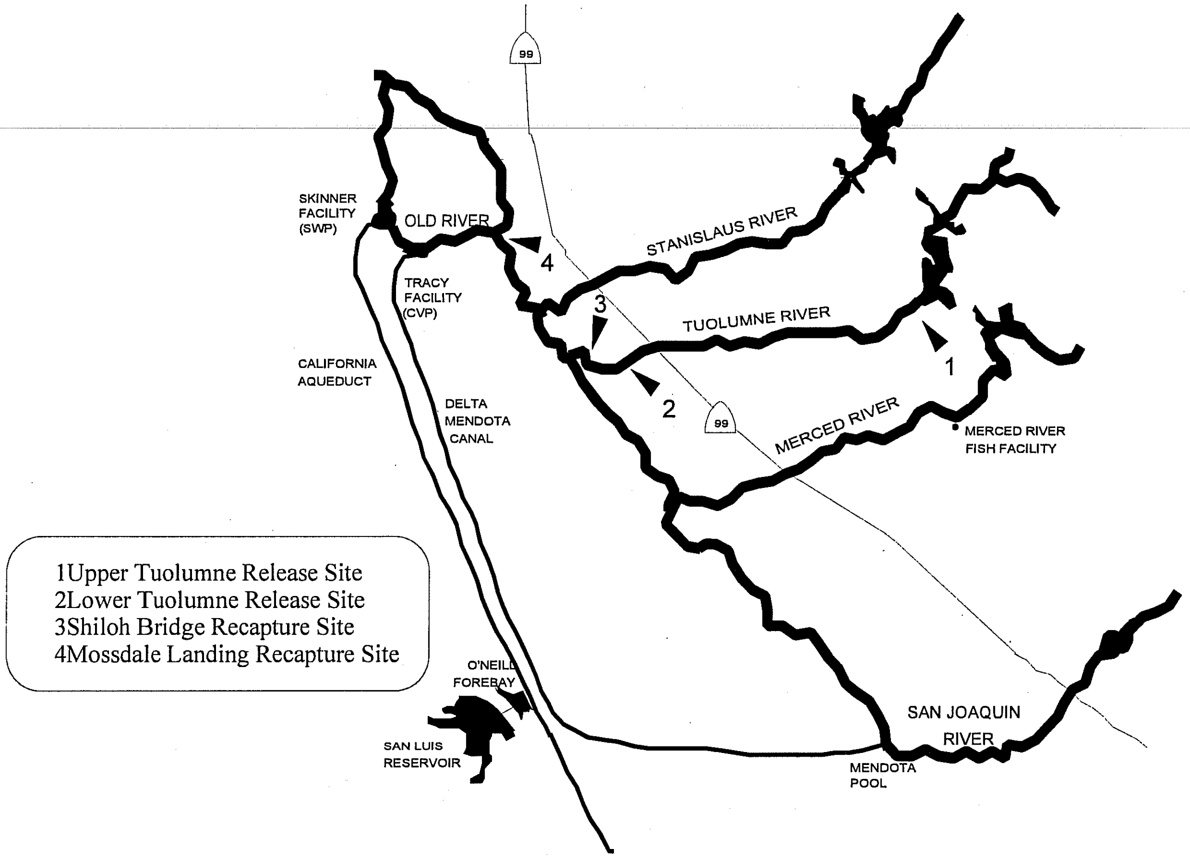


Figure 1. California Department of Fish and Game release and recapture sites for the chinook smolts released into the Tuolumne River.

summarizes the 1997 smolt survival index studies and the first three years of RST evaluations. Information for these evaluations in 1995 and 1996 are summarized previously (CDFG, 1997).

Methods

CWT Test Fish

Juvenile salmon at the Merced River Hatchery (MRH) were fin clipped (adipose fin) and tagged with binary coded-wire tags (CWT, half-size) in March, 1997. The tagged fish were released the following month in two groups, with each group consisting of 3-4 tag codes (Table 1). The test group was released at Old LaGrange Bridge (RM 50.5) and the control group was released at the end of Service Road (RM 6). The release dates were April 22, 1997 for the test group and April 23, 1997 for the control group.

Efficiency Test Fish

Four groups of smolts from MRH (~2,000/group) were marked and released to test RST efficiency (Table 2). RST efficiency is defined as the percentage of a specific group of smolts, released close to the RSTs, that are recaptured. Approximately one release per week was made during RST operation. Each group was dyed with blue dye on either the caudal or anal fin rays with Madajet and Panjet tattooing equipment. These fish were transported in small tanks and released approximately 900 m upstream of the RSTs just after sundown.

Table 1. Tag number, release location and the number of tagged fish released with that tag number into the Tuolumne River in 1997.

Tag#	**Release Location**	**Number of fish**
6-01-11-0604	Service Road	25,250
6-01-11-0605	Service Road	25,700
6-01-11-0606	Service Road	21,550

6-01-11-0607	LaGrange	31,100
6-01-11-0608	LaGrange	29,950
6-01-11-0609	LaGrange	24,550
6-01-11-0610	LaGrange	7,900

Table 2. Information on the efficiency test fish; including date of release, identifying mark, number of fish released and number of fish recaptured.

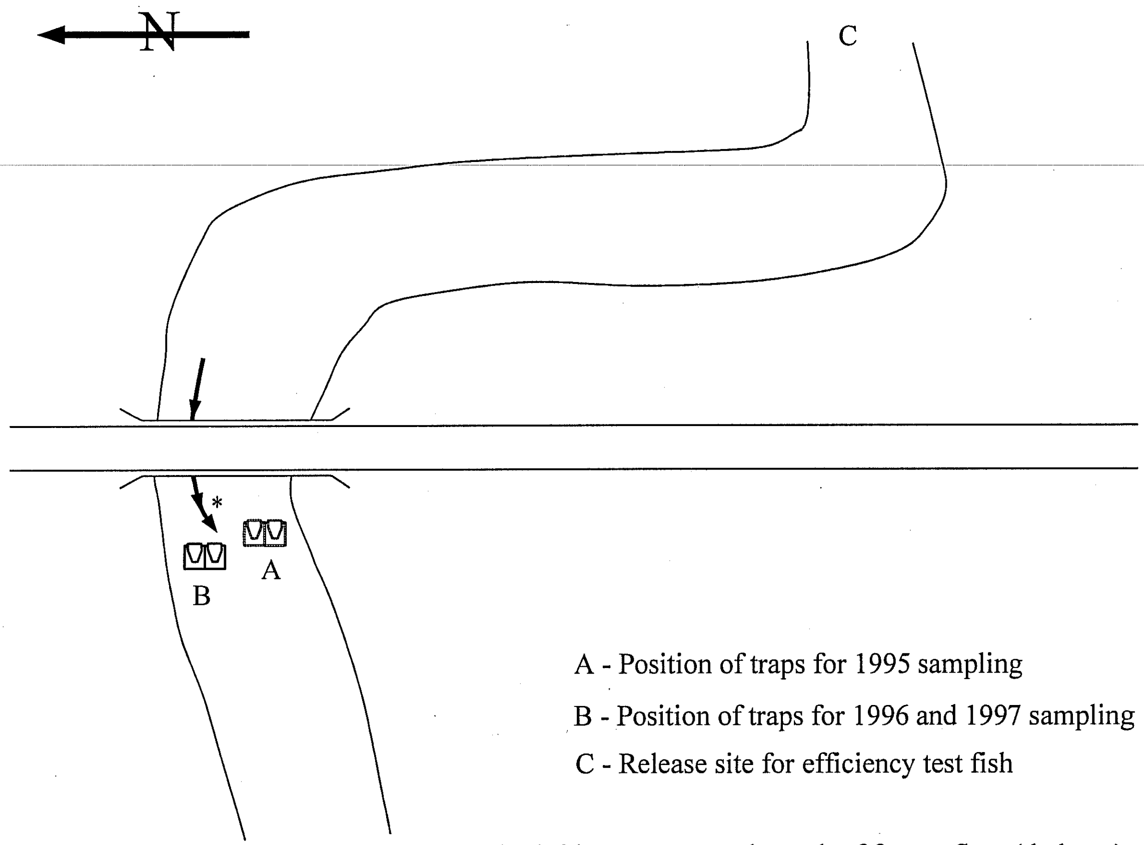
Date	Mark	Number released	Number recaptured
21APR97	Blue-uppper caudal	2149	26
28APR97	Blue-lower caudal	2001	37
05MAY97	Blue-anal	1995	70
12MAY97	Blue-uppper caudal	1487	21

Trap Operation

Simultaneous with the mid-point of a Kodiak trawl survey being performed downstream on the San Joaquin at Mossdale Landing (CDFG, 1996), two 8' rotary-screw traps (RSTs) were deployed and operated at Shiloh Bridge (Fig. 1) in 1997. No channel modifications have been made to enhance the catch efficiency in any of the three years. The RSTs were operated just prior to, during and following the release and passage of CWT tagged and dye-marked smolts for the smolt survival index study. They were operated during the middle of the natural smolt outmigrant period, from Apr. 18th to May 24th, 1997. The two traps were fished side-by-side, 24 hours a day, directly in the thalweg throughout this period (Figure 2). For information regarding the methods and period of operation for the Kodiak trawl at Mossdale Landing see CDFG (1996).

The RSTs were checked twice a day, except when more frequent checks were required to keep the traps operating. Releases of test fish were the primary reasons for more frequent checking. Sampling was performed by a combined effort of CDFG and M/TID.

All fish and debris were removed from the RSTs each time the traps were checked. The fish were separated by species and counted. A subsample (usually all) of the chinook smolts were measured (FL to the nearest mm) and checked for external marks (dye or adipose-fin clips). Smolts with adipose fin clips were retained frozen and assumed to be coded-wire tagged (1/2 CWT). These tagged fish were later thawed, the tags extracted and decoding was performed to determine the group of origin. All untagged or unmarked salmon captured were assumed to be of natural origin. Lengths of other species of fish were visually estimated or occasionally measured.



*Arrow under bridge represents the path of fastest flow (thalweg)

The time, in seconds, that it took each RST to make 10 revolutions was recorded and

Figure 2. Map of the Shiloh Bridge sampling site. Position of the RSTs in 1995, 1996 and 1997 are shown as well as the release site for the trap efficiency testing fish.

water velocity was measured at the center of each RST using a Marsh-McBurney flow meter (a Flowmate 2000). Velocity measurements were 0.5 meters below the water surface. Air and water temperature were recorded with field thermometers, along with general weather conditions. Date and time the fish were removed from the RSTs were also recorded.

Analysis

Graphical evaluations of most data collected were produced for this report. The relationship of a)streamflow and b) time of capture, to the numbers of natural and tagged smolts and their size (mm FL) were assessed graphically. Trap efficiency was evaluated in relation to four variables that might influence it; streamflow, percentage of streamflow that is filtered by the traps, velocity at the mouth of the traps, and size of fish captured. Preliminary regressions were performed to assess the relative strength of the relationships.

A simple estimation of total numbers of chinook salmon smolts passing the RSTs (termed "smolt production index") can be made by multiplying the number of smolts captured each day by the inverse of the RST efficiency at that flow and summing those values over the sampling period. There are however some serious problems with this approach and estimation.

The RSTs are occasionally stopped by debris. Thus, the catch on such a day is limited to less than 24 hours and not necessarily the "total" potential catch. Smolts released during the daytime, for efficiency testing, were not recaptured in the traps indicating that smolts are able to pass by without being detected by the RSTs during the daytime. The duration of RST sampling in all three years (1995, 1996 and 1997) was shorter than the time period during which natural chinook salmon smolts were outmigrating from the Tuolumne River (based on sampling at other locations in the San Joaquin Basin). Although at present, these problems and others not listed may cast doubt on the accuracy of simple estimates for total numbers of smolts, preliminary smolt passage indices were made due to interest in the range of numbers that might be generated.

A low estimate for a smolt production index can be made by multiplying the number of smolts captured each day by the inverse of the RST efficiency that day and summing across sampling days (see Equation 1). The total catch of smolts and the average RST efficiency for the year were used because there is not yet a clearly defined relationship between RST efficiency and physical parameters; and the variation of RST efficiency within a year was small.

$$SP_m = \sum_{i=1}^{m} \frac{N_i}{E_i}$$

1)

Where:

SP_m = Smolt Production index for m days
i = sampling day
m = number of days sampled during the season
N = Number of smolts captured during day i
E = Trap efficiency estimated for day i

A "daytime corrected" smolt production index (Equation 2) can be made by assuming that smolts move at an equal rate in the day and the night and are absent from day samples simply because they avoid the RSTs. Diel correction can then be made by applying a correction factor (D) that is the inverse of the proportion of the day that are night hours. There is evidence from studies in the basin (Cramer and Demko, 1997; Neillands, pers. comm.) that smolts do migrate during both night and daylight hours. Since day and night are nearly equal length the "daytime corrected" production index is calculated by multiplying SP_m by 2.

SP_CL=SP_m TIMES D

2)

Lastly two "high" estimates (Equations 3 and 4) for smolt production indices were produced by multiplying SP_m and the SP_{CL} by a "seasonal correction factor" (Y). The "seasonal correction" factor is used because the RSTs were not operated the entire time that the smolts were outmigrating. In order to estimate the "seasonal correction" factor, temporal catch data from sampling at Caswell on the Stanislaus River (RSTs) and at Mossdale on the San Joaquin River (Kodiak trawl) were used to estimate the percentage of smolts that outmigrated during the Tuolumne River sampling periods. That percentage divided into 100 yields the "seasonal correction" factor (Y).

SP_CM=SP_m TIMES Y

3)

SP_CH=SP_CL TIMES Y

4)

Smolt survival index methodology used since 1986 on the Tuolumne River is described in CDFG (1995 and 1996). This method was used to calculate survival indices for the RSTs and the Kodiak trawl in both years. The calculation method is shown in Equation 5:

S hat = {R 1*M 2} over {R 2*M 1}

5)

Where:

$\bullet\bullet$ = Survival rate index
R_1 = Number of recaptures from test release group
R_2 = Number of recaptures from control release group
M_1 = Number effectively released for test release group
M_2 = Number effectively released for control release group

Results

Fifty seven natural salmon smolts were captured at the Shiloh Bridge RSTs in 1997 (Fig. 3) . That was fewer smolts than either of the two preceding years (Appendix A) inspite of the highest antecedent spawning escapement of all three years. The low smolt numbers are thought to be caused in part by the catastrophic flood that occurred in the Tuolumne River in early January of 1997 (Fig. 4).

The catch of smolts was not uniform throughout the 24 hour cycle. Figure 5 shows that few fish were captured in the daylight hours.

A test group of 93,500 tagged smolts was released in the Tuolumne River at Old LaGrange Bridge and a control group of 72,500 tagged smolts was released in the Tuolumne River at the end of Service Road. Two hundred and thirty adipose fin clipped smolts (174 had tags) were recaptured in the RSTs. Figure 6 shows the catch of tagged smolts during the month and a half of sampling.

Figures 7 and 8 show the fork lengths of the natural and CWT smolts in 1997. Average fork length changed little during the sampling period for natural smolts but rose slightly for

CWT smolts.

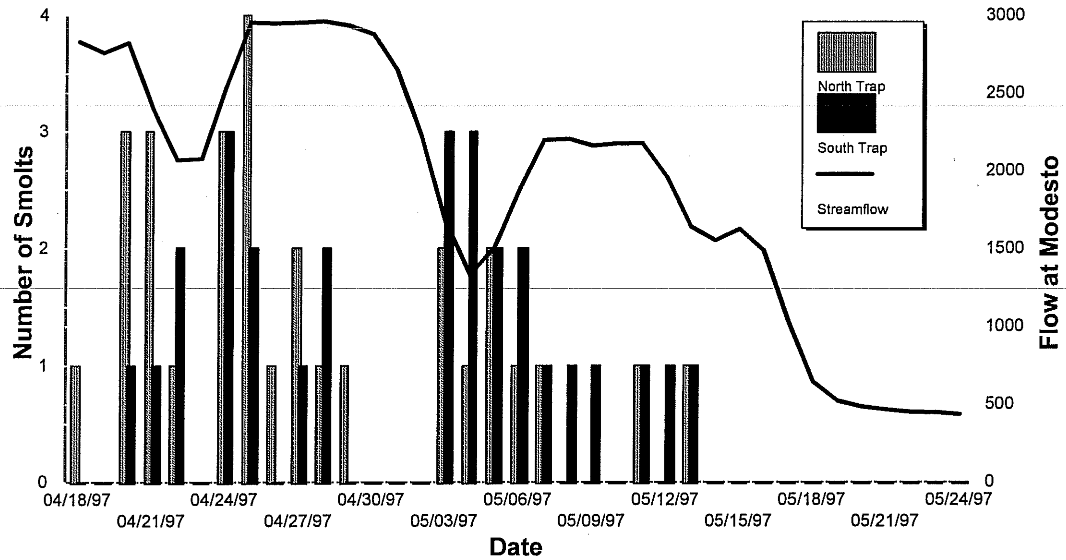


Figure 3. Natural chinook smolts captured in both RSTs and the streamflows at Modesto on the previous day in 1997.

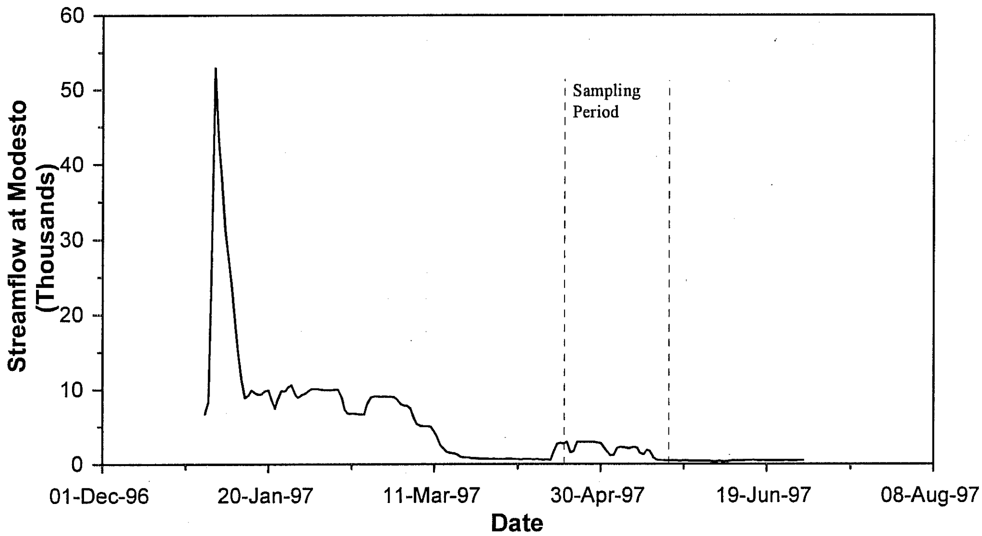
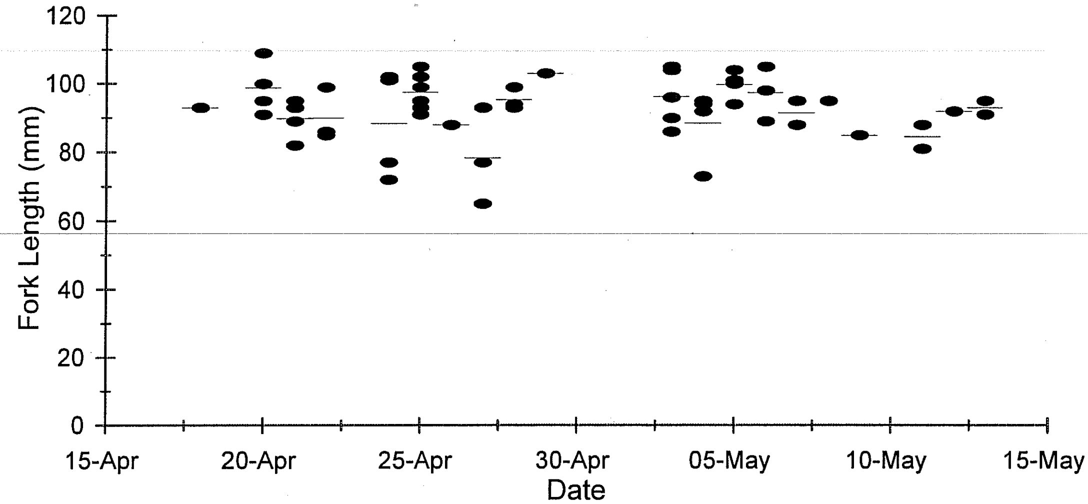
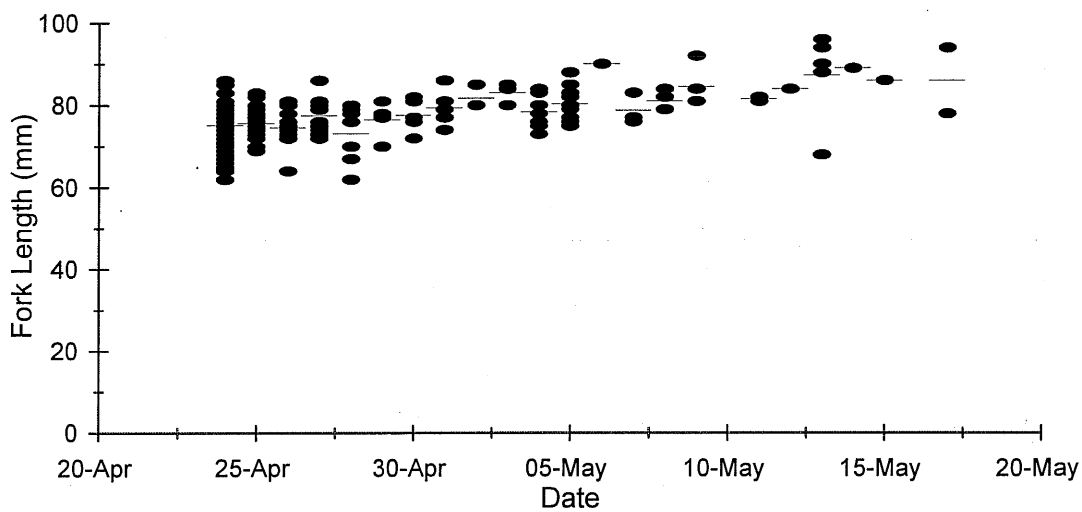


Figure 4. Streamflows at Modesto from January 1 to June 30, 1997. Period during which the RSTs were sampling is shown with dotted lines.



Date

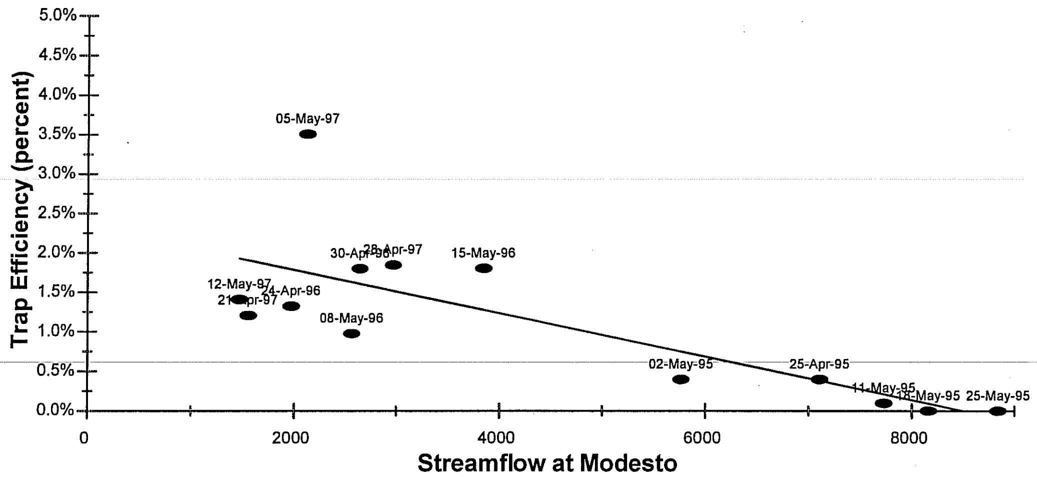
Figure 5. Diel variation in numbers of natural chinook smolts captured in Tuolumne River RSTs during 1997.



1997.

Figure 7. Average fork lengths of natural chinook salmon smolts in the Tuolumne River in 1997. The dots are the actual data points and the bars represent the average fork length for the day.

Figure 8. Average fork lengths of coded-wire tagged (CWT) chinook salmon smolts in the Tuolumne River in 1997. The dots are the actual data points and the bars represent the average fork length for the day.



The capture efficiency of the RSTs was tested 4 times in 1997. These data were combined with the data from 1995 and 1996 to allow more complete evaluation of relationships with biotic and abiotic factors that might influence trap efficiency. There appear to be linear relationships between; a) RST efficiency and streamflow (Figure 9) and b) RST efficiency and percent of flow that was filtered by the traps (Figure 10).

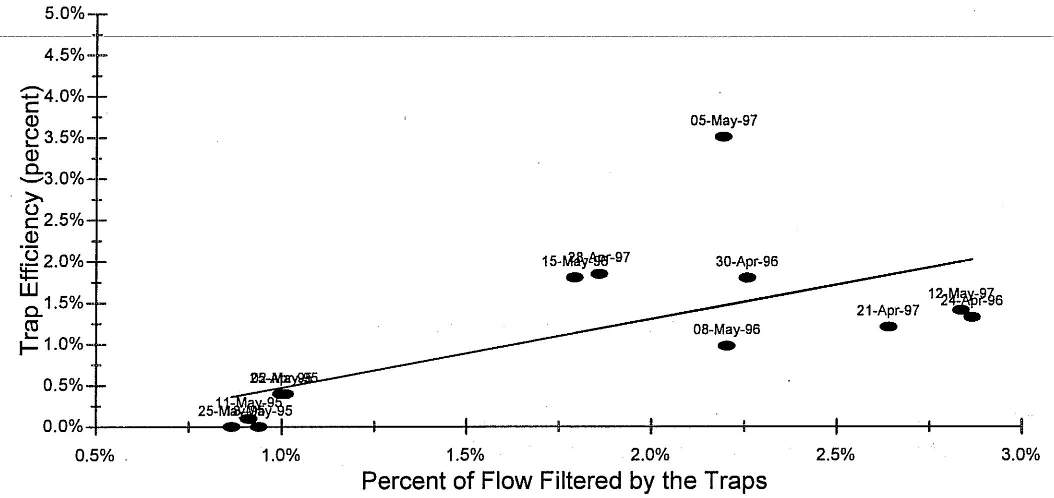
Figure 11 indicates a linear relationship of velocity to RST efficiency. Fork length of smolts released does not seem to be related to RST efficiency (Fig. 12). Many of the factors that are affecting the capture of smolts actually covary as can be seen in Figure 13. There is more that can be evaluated in the data. A daily summary is presented in Appendix B.

Calculation of preliminary smolt production indices for 1995, 1996 and 1997 are presented in Table 3. Survival estimates were developed for all three years from catch at both the RSTs at Shiloh Bridge and the Kodiak trawl downstream at Mossdale. These data are presented in the Table 4.

Figure 9. Percent of test fish recaptured (RST efficiency) that were released ~900m upstream of the RSTs

compared to streamflow at Modesto. Linear regression line has r-squared of 0.57.

Figure 10. Percent of test fish recaptured (RST efficiency) that were released ~900m upstream of the RSTs compared to percent of the streamflow at Modesto filtered by the RST. Linear regression line has



r-squared of 0.41.

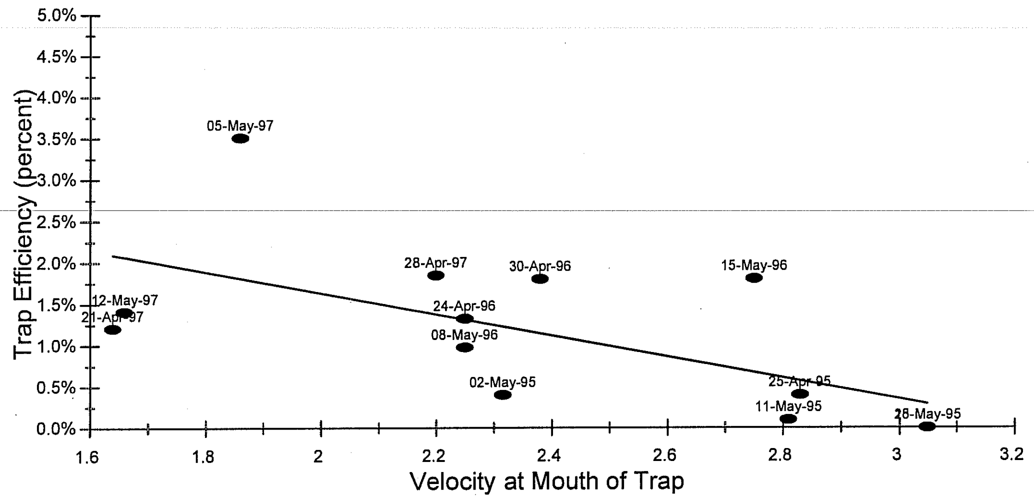


Figure 11. Percent of test fish recaptured (RST efficiency) that were released ~900m upstream of the RSTs compared to velocity at the mouth of the RSTs. Linear regression line has r-squared of 0.39.

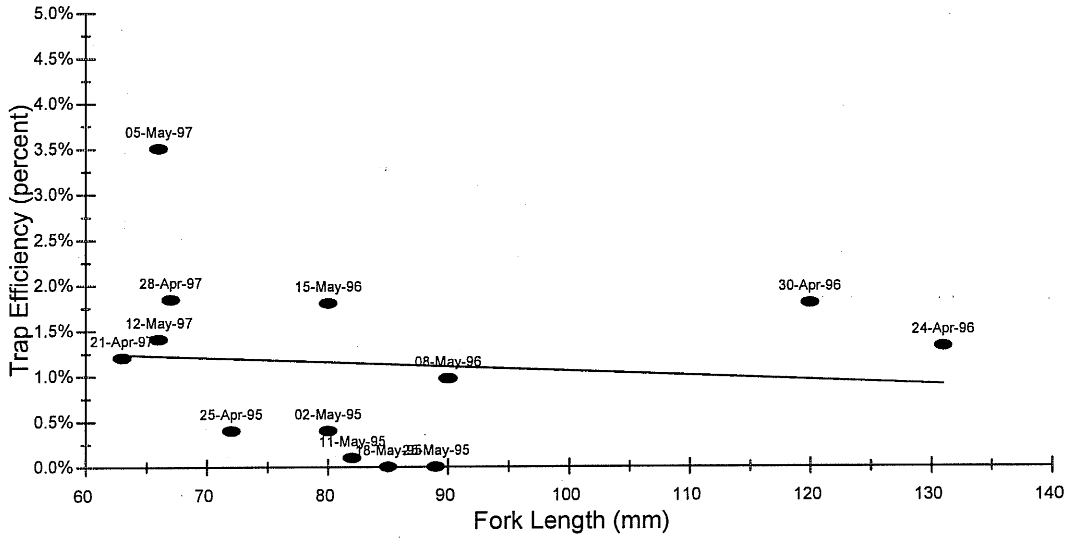
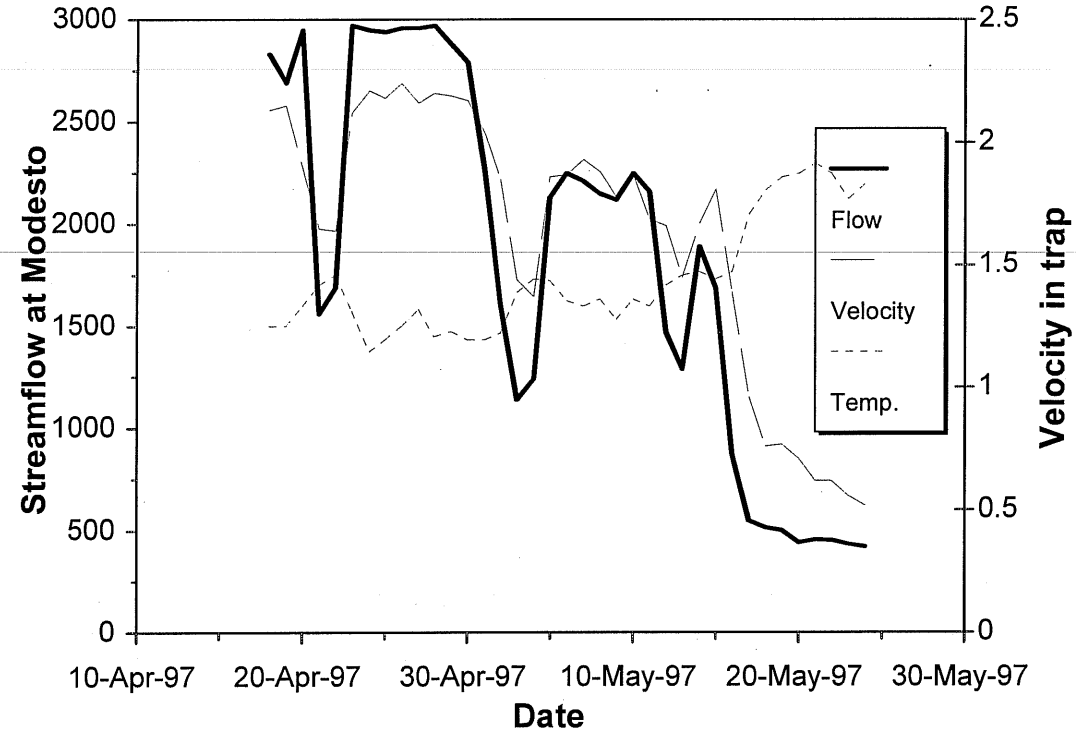


Figure 12. Percent of test fish recaptured (RST efficiency) that were released ~900m upstream of the RSTs compared to the average fork length of the smolts in the test groups. Linear regression line has r-squared of 0.01.



Note-Temp. refers to water temperature. The values are on the left y-axis and have been multipied by 100

Figure 13. Streamflow at Modesto, Velocity of water entering the trap and water temperature at the trap site throughout the sampling period. Water temperature shares the same axis with streamflow and had to be multiplied by 100 to be viewable.

Table 3. Preliminary chinook salmon smolt production estimates for the Tuolumne River during 1995, 1996 and 1997.

Year	Number of smolts captured	Efficiency estimate	SP_m	SP_{CL}	SP_{CM}	SP_{CH}
1995	141	0.0090	15,667	31,333	21,933	43,867
1996	630	0.0156	40,385	80,769	56,538	113,077
1997	57	0.0200	2,850	5,700	3,990	7,980

Table 4. Chinook salmon smolt survival indices and associated data for the Tuolumne River in 1995, 1996 and 1997.

Year	Release Site	Number of smolts released	Mean Flow	Number Captured at Mossdale	Number Captured at Shiloh	Survival Index at Mossdale	Survival Index at Shiloh
1995	Upper	83500	7600	58	11	0.80	0.64
	Lower	53300		46	11		
1996	Upper	67200	3000	64	222	0.31	1.25
	Lower	50500		156	133		
1997	Upper	93500	2100	32	13	0.42	0.06
	Lower	72500		59	161		

Discussion

The increases in numbers of natural smolts captured, generally appear to follow large changes in flow (Fig. 3). The low numbers of natural smolts sampled in 1997 make it difficult to demonstrate this relationship but still the first three rapid changes in flow that were greater than a fifth of the total flow (change in less than a week) are associated with spikes in the number of smolts. A more complete evaluation of the increases and decreases in catch over all three years will be made in subsequent reports.

Movement of the smolts seems to be effected by the time of day. This may be simply a result of smolts being more able to avoid the RSTs when there is more light, the smolts may not move during the daytime, or both avoidance and lack of movement may be causing these results. This suggests light (as effected by such things as moon phase, turbidity, time of day and weather) as a possible factor in addition to streamflow effecting the outmigration of smolts. Subsequent sampling seasons will involve more complete evaluation of the effects of light on smolt capture.

RST efficiency evaluations are an area of investigation that needs more intensive work. These data are crucial to any index of smolt production for the river. The gaps in the present data will need to be filled in subsequent years. The apparent linear relationships, between RST efficiency and streamflow as well as RST efficiency and percent of the flow filtered by the traps, may change drastically as sampling is performed in low flow years. An independent evaluation of RST efficiency needs to be performed as well. Hydroacoustic sampling or radio-tagged smolts could provide independent information to evaluate the present RST efficiency testing and help evaluate movement of smolts during the daytime.

Our indices of smolt production are much lower in 1997 than in previous years. The extremely high flows in January of 1997 one of the possible factors responsible for this low number. The low smolt numbers are thought to be caused in part by the catastrophic flood that occurred in the Tuolumne River in early January of 1997. Streamflows exceeding 50,000 cfs were recorded. As a result of erosion associated with overland flows that occurred during this first use of the spillway at New Don Pedro Reservoir, large amounts of fine sediment were discharged to the lower Tuolumne River. Considerable bedload movement occurred in some areas due to the high velocities.

There is some question as to whether or not this will result in lower escapements 2-1/2 years later. Emergent fry may have been swept into the Delta early in the rearing period and reared there rather than in the river itself. A daily estimate of production, using Equation 1, will be made for all three years in subsequent reports. This will require the development and testing of a relationship between trap efficiency and some physical variable such as flow so that the trap efficiency can be estimated for each day.

Thus far, survival indices based on RSTs at Shiloh Bridge appear erratic when compared to Kodiak trawl-based indices downstream at Mossdale. And, the RST survival indices do not appear to be related to flow in the Tuolumne River. The best use of the RSTs maybe for determining levels of production in each year. In order to do that they must be operated for a longer period of time.

CDFG is analyzing all the smolt survival study results from the Tuolumne River studies since 1986. This is being done in order to refine our understanding of a) the recovery and survival relationships at all sites, b) factors that are causing variability in these results, and c) to make recomendations for improvements in the smolt survival monitoring protocol used pursuant to the 1996 settlement agreement. Subsequent reports will utilize trap efficiency estimates to calculate the total number of CWTs that pass the traps. This may result in an alternate approach to evaluating smolt survival.

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Appendix A. Numbers of natural and CWT chinook smolts captured in two RSTs deployed side by side at Shiloh Bridge on the Tuolumne River in Stanislaus County, CA. Only one trap was used after May 25th in 1995 and May 17th in 1996. Blanks indicate when no sampling occurred. (Total CWT includes adipose-clipped fish with no tag recovered)

Date		1995				1996				1997		
	Natural	Upper CWT	Lower CWT	Total CWT	Natural	Upper CWT	Lower CWT	Total CWT	Natural	Upper CWT	Lower CWT	Total CWT
18-Apr					11				1			
19-Apr					12				0			
20-Apr					8				4			
21-Apr					16				4			
22-Apr					15			0	3			
23-Apr					19				0			
24-Apr					8				6	0	77	103
25-Apr	0				19			0	6	0	17	24
26-Apr	5				41			0	1	0	11	15
27-Apr	4				23	40	41	99	3	0	10	13
28-Apr	2				64	83	44	151	3	0	6	9
29-Apr	8				18	32	4	47	1	1	3	4
30-Apr	7				30	19	12	39	0	0	2	5
01-May	2				16	8	3	14	0	0	5	5
02-May	8				20	6	5	12	0	0	2	3
03-May	12				13	2	4	8	5	0	3	3
04-May	6				18	6	2	8	4	1	7	9
05-May	6	1	1	2	17		1	1	4	2	8	12
06-May	10	1	3	6	3		1	1	3	1	0	1
07-May	4			0	9	2	1	5	2	1	1	3
08-May	2			0	23	4	2	9	1	1	1	4
09-May	2			0	52	7	1	9	1	1	3	4
10-May	4		2	2	23			1	0	0	0	0
11-May	1	1		1	18	3		3	2	0	2	2
12-May	5			0		1		4	1	0	1	1
13-May	1			0	18	2	2	4	2	3	0	5
14-May	2	1	1	2	25	1	2	4	0	2	0	2

15-May	3			0	46	3		6	0	0	1	1
16-May	4	2		2	8	1		1	0	0	0	0
17-May	8	1		1	9			0	0	0	1	2
18-May	5		2	2	1			0	0	0	0	0
19-May	10	1		1					0	0	0	0
20-May	4		1	1					0	0	0	0
21-May	3			0	0			0	0	0	0	0
22-May	1			0					0	0	0	0
23-May	4			0					0	0	0	0
24-May	1		1	1					0	0	0	0
25-May	1	1		1								
26-May	0			0								
27-May	0			0								
28-May	4		1	1	6	2		2				
29-May	1			0	1			2				
30-May	1	1		1								
31-May	0			0								
01-Jun	0			0								
TOTAL	141	10	12	24	610	222	125	430	57	13	161	230